Yellowstone National Park Evaluates Renewable, Alternative Fuels

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Yellowstone was designated by Congress as the world's first national park in 1872 and is one of our nation's greatest natural treasures, a place to be left unimpaired for future generations. Its popularity is evident by increasing number of visitors throughout the years. Fifty million people visited Yellowstone during the first 100 years of its existence—the Park was visited by another 50 million people during the next 25 years. In the summer, it is transformed into a virtual city with 1.5 million people visiting in July and August alone. The nearly 900,000 automobiles that travel in the Park each year burn millions of gallons of fuel and produce tons of pollution, endangering this pristine environment. Because of these ever-burgeoning numbers, park staff has made the commitment for Yellowstone to be one of the National Park Service flagships for exploring possibilities to reduce pollution by using alternative fuels.

These efforts experimented with the use of environmentally preferable fuels. Yellowstone's winter and summer dictate two distinctly different travel modes and a number of transportation fuel requirements. Senior Yellowstone staff evaluated alternate transportation fuels in the early 1980s, but they were unable to find any fuel that was readily available and affordable in the immediate vicinity. In late 1993, Montana energy office staff began discussions with the Yellowstone planning office about potential cooperative projects. By May 1994, several partnered activities had been started. Yellowstone's hot problems included complaints of noise and emissions of snowmobiles, and these concerns were addressed the following year. The more immediate summer concerns involved visitor complaints about some and odor of diesel engines in the Park. Although Yellowstone complied with all EPA air quality regulations, it was not what visitors expected. At that point, DNRC, now DEQ, wrote a grant proposal to DOE conduct a pilot study of biodiesel in Yellowstone to reduce the impacts of diesel transportation fuel in the tourism industry.

The pilot demonstration project, commonly referred to as the "Truck in the Park" Project, is a multi-prong effort to reduce air pollution and address human health concerns. The project supplied data and information on safety, performance, emissions, and benefits of using a regionally produced, non-petroleum based fuel in a test vehicle, and built partnerships among the Department of Energy, states of Montana and Wyoming, the National Park Service, the University of Idaho, regional businesses, and regulators. The technical results on emissions, performance, safety, and other findings will soon be available in a final technical report.

The fuel is produced from canola or rapeseed plants. The production process involves reacting oil from the seeds with an alcohol such as ethanol, and separating the esters from glycerol to produce a fuel to be used in a diesel engine. The fuel is referred to as "biodiesel."
One notable fact about the pilot demonstration is that no modifications were made to the demonstration vehicle, which was equipped with a stock engine and fuel system.

The "Truck in the Park" Project was designed with two purposes: to define a market for biodiesel and to provide data on emissions and performance that could be used by land managers, regulators, and providers of commercial tourism transportation. This project was a first-step to reduce environmental impacts resulting from diesel fuel use in the tourism industry. Basically, the project placed an unaltered diesel pickup truck into service in Yellowstone National Park, fueled this truck with 100 percent rapeseed ethyl ester (REE), and monitored performance and emissions. Data were collected to determine the reliability, benefits, and costs of using biodiesel in Yellowstone National Park and the surrounding region. The project included fuel characterization, detailed performance and emissions tests before and after the experiment, and other quality control testing to document benefits and costs. This presentation describes the implications of these results for the Yellowstone region and challenges of bringing this fuel technology to market.

The University of Idaho (UI) developed the fuel from canola and rapeseed oil. Previous UI research indicates that the biodiesel fuel has greater biodegradability and reduced emissions, odor, and smoke than petroleum diesel fuel. At the outset of the Truck in the Park Project, biodiesel was at the stage of development where a higher value market, such as this tourist-related application, was the next logical step on the way to commercialization. The project developed into two phases: Phase 1 was to answer technical questions and address the feasibility of operating biodiesel. As Phase 1 began to prove itself successful, Phase 2 developed to address additional questions, trade-offs and possible specific applications of biodiesel. The objectives of Phase 1 were to determine the impacts and results from using biodiesel. Specifically, these objectives were to:

- Identify differences in safety and operation when using biodiesel as compared to conventional diesel fuel.
- Determine problems and possible solutions of using biodiesel at high elevations and temperatures that range from 90 degrees F. to –35F.
- Determine changes in performance and emissions (with and without an exhaust catalyst) over 100,000 miles of operation. Performance would be measured periodically with chassis dynamometer tests. Emissions would be measured at the beginning and end of the project.
- Develop information on costs, benefits and trade-offs.
- Distribute information and demonstrate to potential users the benefits and drawbacks of biodiesel use in environmentally sensitive areas.

A concern voiced by park personnel was that the odor of the biodiesel might attract bears. The exhaust from a diesel engine fueled with REE smells like a French fry cooker, and might attract bears if they connect the scent to a food reward. Attracting bears to vehicles operated by humans was to be avoided. An analysis was conducted at Washington State University Bear Research Conservation and Education Facility in Pullman, Washington to determine if bears were attracted to the scent of biodiesel. Human and wildlife safety concerns were the main reasons for the tests. The conclusion was that biodiesel is no more attractive to bears than conventional diesel fuel (Biel *et al.* 1995). These data are important for other users located in environmentally sensitive applications.

Operations and refueling facilities were based in Mammoth Hot Springs where assistance from Park personnel was easily accessible, if needed. UI provided a Materials Data Safety Sheet for the fuel, and supplied data on the emissions, biodegradability, and toxicity. Water quality specialists in state environmental agencies were informed about differences in spill cleanup strategies between biodiesel and diesel fuel. UI studies performed tests on acute dermal toxicity. This was all part of introducing a new fuel into an existing infrastructure.

Diesel engines are used extensively in the Park (161 in Yellowstone NPS duty alone) and tourism industry for road maintenance, snow groomers, back-up generators, and tour buses. A combination of fuel availability and successful experience with the Cummins B series engines helped the project target the engine to be used in the project. Dodge Truck Division donated the use of a 1995 Dodge 3/4 ton 4X4 pickup with 5.9-liter Cummins B diesel engine for the project. Montana DEQ was the project coordinator, UI provided technical assistance and fuel, and Yellowstone personnel operated the truck and performed maintenance. It was equipped with a standard winterization package for diesel engines. No modifications were made to the truck's engine or fuel system.

By May 1999, the truck has been driven over 98,000 miles without any fuel related problems. Initially, the engine lubrication oil was changed and sampled for heavy metals and viscosity every 6,000 miles. The analysis of the first lube oil sample showed a high silica content. The manufacturer suggested that the source was probably due to the manufacturer’s final engine preparation.

The lube oil sample taken during the first cold weather (December 1995) reported a change in lube oil viscosity. The test indicated possible fuel dilution. However, the test was not designed to detect biodiesel, so we did not know what caused a change in viscosity reading. The manufacturer recommended the winter interval for oil changes in this engine should be about 3,000 miles due to the increased idling in winter, as has been the manufacturers’ recommendation for this engine type for cold weather operation. The engine oil, filter and fuel filter were changed and sent for analysis during these regular servicing intervals and fuel dilution was never again detected.

In addition to the oil analysis, periodic chassis dynamometer and injector inspection tests were run to monitor engine performance. These were performed by UI in March 1995, August 1995, March 1996, November 1997 and June 1998. As expected, the engine produced about 6 percent less power with biodiesel then with conventional diesel fuel because of the lower fuel density of biodiesel. Drivers did not notice the difference.

The final step in performance monitoring was the disassembly and inspection of the engine by Cummins Intermountain, Pocatello, Idaho. The inspection occurred in July 1998. These results have been analyzed and a report is available upon request.

Detailed emissions tests were conducted using the federal test protocol at the Los Angeles County Metropolitan Transportation Authority Emissions Test Facility (an EPA-approved facility). Results of the first set of emissions tests taken after the initial break-in period were reported by Peterson *et al.* (October 1995). Particulate samples were analyzed for polyaromatic hydrocarbons (PAH) and genotoxicity was investigated using a bioassay by Kado (1997). These tests from samples taken at the first emissions tests showed toxicity and mutagenicity decreased with increasing percentages of biodiesel. The amounts of volatile organic compounds (VOC) were significantly decreased with 100 percent biodiesel. The emissions were again tested after 86,000 miles to determine the effects of biodiesel on the engine emissions after a set amount of time (the goal was 100,000 miles or 3 years). A final report expected in 1999 will compare the polyaromatic hydrocarbons (PAH) and bioassay results of the first and second series of emissions tests.

For criteria emissions, both sets of tests showed use of biodiesel fuel reduced carbon monoxide (CO), total unburned hydrocarbons (HC), and oxides of nitrogen (NO_X). The catalytic converter operated more efficiently when biodiesel was used. The preliminary findings indicate that emissions have not increased over time, and the catalytic converter does not appear to be fouled by the use of biodiesel. A detailed comparison of regulated emissions data is given by Taberski *et al.* (October 1998).

Fuel type and quality were crucial to the success of this project. The results of emissions and performance testing over the length of the project would be worthless unless a uniform, standardized fuel was used. Fuel used was 100 percent rapeseed ethyl ester as a worst-case scenario from a manufacturer’s point of view, to develop data for engine warranty purposes. UI adopted the German DIN biodiesel specifications and confirmed this standard by running the American Society of Agricultural Engineers (ASAE) tests on each batch of fuel delivered to the Park.

Koch Agricultural Services Inc, Great Falls, supplied most of the vegetable oil feedstock. The feedstock oil was off spec (not food grade in color) degummed canola oil, the edible variety of rapeseed oil. For reacting with the oil, JR Simplot, Caldwell, Idaho, donated fuel-grade ethanol made from potato waste and the catalyst used for processing. UI reacted the canola oil with the fuel-grade ethanol and catalyst to produce 6,560 gallons of biodiesel fuel (Peterson *et al.* August 22, 1995 and 1998). UI conducted quality assurance tests on the fuel, and delivered small quantities to the Park at regular intervals. The Park Service stored the biodiesel fuel at Mammoth in a 10,000-gallon, unheated, above ground tank. The cloud point characteristics of biodiesel originally caused concern during low ambient temperatures, but it was soon realized that the canola ethyl ester biodiesel fuel would flow from the large, unheated, gravity flow tank at temperatures as low as –10F if the nozzle was first cleared of solidified biodiesel. No cold-flow or other petroleum additives were used in the biodiesel.

CONCLUSIONS AND FOLLOW-UP ACTIVITIES

This technical phase of the project will soon be completed with several technical reports now under development. We have been able to determine that the effects of biodiesel on criteria emissions with and without the catalytic converter were unaffected over the course of time, and that no new compounds are generated in blends of biodiesel with conventional diesel. The project also developed data for use in modeling air quality so the impacts can be assessed before a large-scale conversion is implemented. The information also shows that biodiesel or a blend may be the fuel of choice for restricted or poor air dispersion conditions. Tests also showed that the sweet odor of biodiesel exhaust does not attract bears, which was a concern to Park and land management officials.

Operating the truck for three Yellowstone winters (95/96, 96/97, 97/98) demonstrated that normal cold-weather diesel modifications were sufficient to enable the use of biodiesel. The truck was parked in a garage at night or plugged into an outlet when night temperatures dipped below –10F. The truck failed to start on only one occasion with a daytime temperature of -37 F, a time when most things were only running for cover.

Although fuel consumption increased 14 percent (by weight measure) from the initial emission test to the final emissions test, no apparent reason for the increase was readily seen. Records were reviewed, and it appears that the increase in fuel consumption is due to increased resistance in the drive train, since power for these tests was measured at the wheels. Changes such as different tires and other changes affecting power transmission affect this increase in drive train resistance.

The benefits of biodiesel include reduced toxicity, emissions, smoke, unpleasant odor, and increased safety and biodegradability. One of big challenges was to accumulate a lot of miles on the truck in a short period of time. Because Mammoth was the only location to refuel, this proved difficult. As a consequence, the Park installed a 300 gallon auxiliary tank in the bed of the truck, which afforded us the opportunity to travel up to 5,000 miles before having to refuel. This proved to be critical to the success of the project.

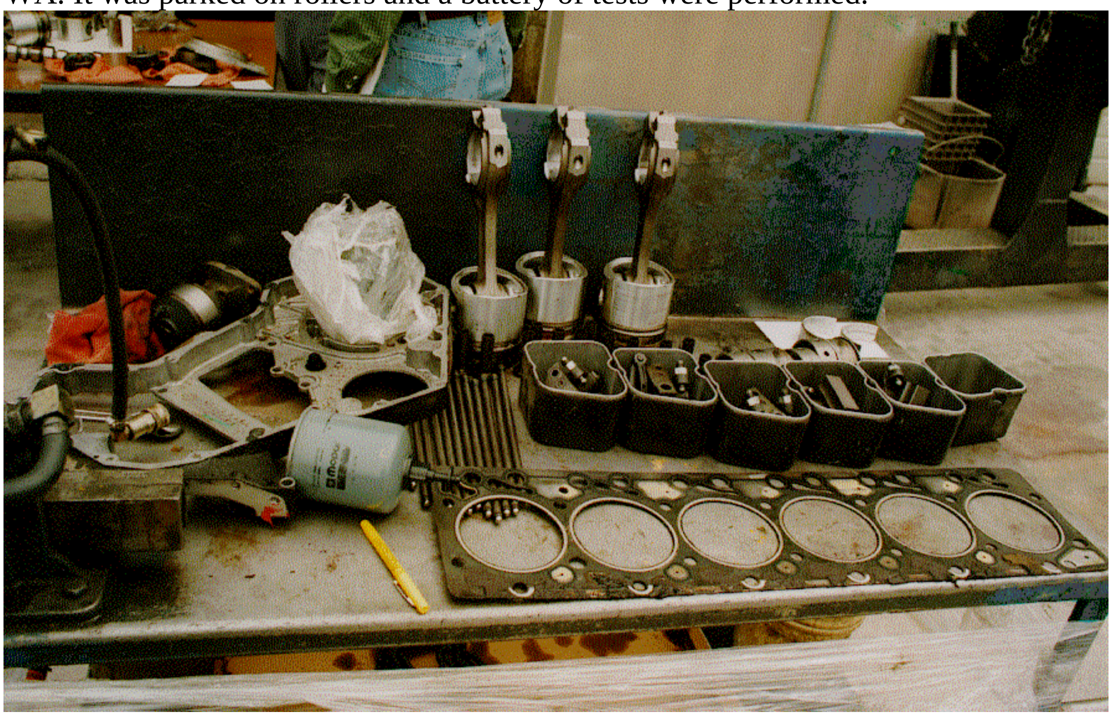
The Truck in the Park, “French fry truck” or "canola truck" as it was referred to in the local communities, provided an introduction to alternate fuels in the greater Yellowstone Region. It received recognition from EPA for the environmental partnership that developed to conduct the project. People drawn to the truck pointed out that the U. S. should be doing more of this type of work. Park personnel identified six most commonly asked questions by the public:

1) What changes were made to the engine? No modifications were made to the engine or truck fuel system.
2) What was the mileage? About 16.3 mpg, or 1 mile per gallon less than conventional diesel fuel.
3) How did it perform? For the most part drivers did not notice much of a difference in performance (Peterson Survey, 1997).
4) How much did the fuel cost? For this project, about $7.50 per gallon which includes the emissions tests. A commercial-scale process could produce biodiesel for $2-$3.50 per gallon, but no developer has stepped up to produce the 500,000 gallons per year to make the fuel a viable option in the Yellowstone tourism trade.

5) What is the yield of fuel per acre? About 100 gallons of rapeseed oil per acre, net.
6) When will this fuel be available to the public? The fuel is available for public use in Germany, France, and Austria. A regional producer is needed before it is available here.

As the technical phase of the project concludes, phase 2 re-assembled the engine to working condition to allow the Truck in the Park to become part of Yellowstone's historic vehicle collection, to be parked along side this 1917 White touring car, one of the first vehicles in the Park.

The truck underwent dynamometer tests every six months at this facility in Spokane, WA. It was parked on rollers and a battery of tests were performed.



Engine tear-down for this study after 92,800 miles. Notice the lack of any carbon build up.

One of the bears involved in the bear attractant study at Washington State University, Pullman, WA.

The truck was donated by Dodge Truck, Inc.


The project received support from a wide variety of sponsers. The truck is picutred here at the Montana State Capitol in Helena, Montana in April, 1995. The Montana Legislature approved seed money for the project.

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